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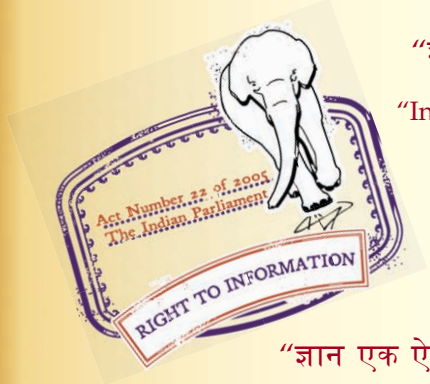
IS 3400-3 (1987): Methods of test for vulcanized rubbers, Part 3: Abrasion resistance using a rotating cylindrical drum device [PCD 13: Rubber and Rubber Products]



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IS : 3400 (Part 3) - 1987
(Reaffirmed 2003)

Indian Standard

METHODS OF TEST FOR VULCANIZED RUBBERS

PART 3 ABRASION RESISTANCE USING A ROTATING CYLINDRICAL DRUM DEVICE

(First Revision)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Indian Standard

METHODS OF TEST FOR VULCANIZED RUBBERS

PART 3 ABRASION RESISTANCE USING A ROTATING CYLINDRICAL DRUM DEVICE

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards on 10 November 1987, after the draft finalized by the Rubber Products Sectional Committee had been approved by the Petroleum, Coal and Related Products Division Council.

0.2 This standard was first published in 1965 and was based on ISO/R 33 — 1957 'Du Pont constant load method of measuring abrasion resistance of vulcanized material and synthetic rubbers', issued by the International Organization for Standardization (ISO), which has since been withdrawn.

0.3 This first revision is based on ISO 4649-1985 'Rubber — Determination of abrasion resistance using a rotating cylindrical drum device'. This method prescribes DIN abrasion tester using rotating and non-rotating test piece.

0.4 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

1. SCOPE AND FIELD OF APPLICATION

1.1 This standard specifies a method for determination of resistance of rubber to abrasion by means of a rotating cylindrical drum device.

1.2 The method involves the determination of volume loss of a rubber test piece through abrasive action by rubbing over a specified grade of abrasive cloth because factors such as the grade of abrasive particles, adhesives used in the manufacture of cloth, and contamination and wear by previous testing, lead to variations in the absolute values of abrasion loss. All tests must be comparative, standard rubbers being included so that the results may be expressed either as relative volume loss referred to a calibrated abrasive cloth or an abrasion resistance index referred to a standard rubber.

No close relation between the results of this abrasion test and service performance may be inferred.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Abrasion Resistance—The resistance to wear by mechanical action upon a surface.

NOTE — For the purpose of this standard, the abrasion resistance is expressed eiher as a relative volume loss referred to a calibrated abrasive cloth or as an abrasion resistance index referred to a standard rubber.

2.2 Relative Volume Loss — The volume loss, in cubic millimetres, of the test rubber after being subjected to abrasion by an abrasive cloth which would cause the appropriate standard rubber (*see* **B-1**) to loose a mass of 200 mg under the referred conditions of test for method A, namely, a distance of 40 m, a load of 10 N and using a non-rotating test piece.

NOTE — The higher the relative volume loss, the lower is the abrasion resistance.

2.3 Abrasion Resistance Index — The ratio of volume loss of a standard rubber to the volume loss of the test rubber measured under the same specified conditions and expressed as a percentage.

3. PRINCIPLE OF THE METHOD

3.1 The principle of the method involves subjection of a cylindrical rubber test piece to the action of an abrasive cloth of specified abrasive grade at a specified contact pressure over a given area.

Abrasion takes place over one of the flat end surfaces of the cylindrical test piece, the abrasive cloth being attached to the surface of a rotating cylindrical drum against which the test piece is held and across which it is traversed.

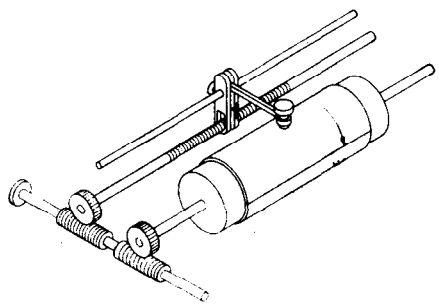
The loss in mass of the test piece is determined and the volume loss is calculated from the density of the material.

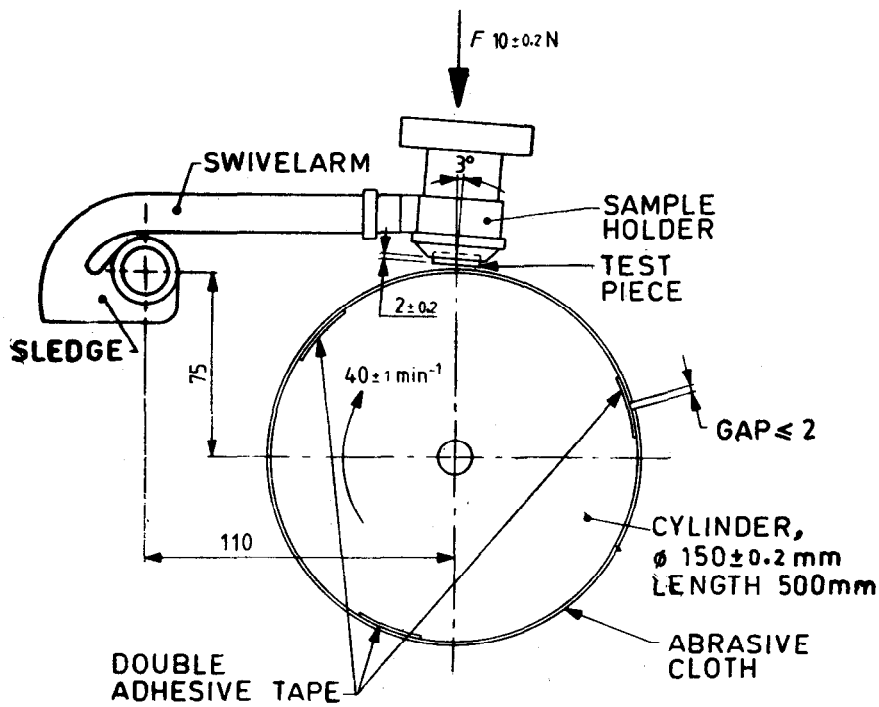
4. APPARATUS AND MATERIALS

4.1 Abrasion Machine — The test apparatus (*see* Fig. 1) consists of a laterally movable test piece holder and a rotatable cylinder to which the abrasive cloth (*see* **4.2**) is fixed.

The cylinder shall have a diameter of 150·0 ± 0·2 mm and a length of about 500 mm and shall be rotated at a frequency of 40 ± 1 min^{-1}, the direction of rotation being as indicated in Fig. 1.

The test piece holder shall consist of a cylindrical opening, the diameter of which may be adjusted from 15·5 to 16·3 mm, and a device for adjusting the length of the test piece protruding from the opening to 2·0 ± 0·2 mm. The holder shall be mounted on a swivel arm which in turn is attached to a sledge which may be moved laterally on a spindle. The lateral displacement of the holder shall be 4·20 ± 0·04 mm per revolution of the drum. Suitable attachments may be provided to rotate the test piece during the test run by rotation of the test piece





All dimensions in millimetres.

FIG. 1 SCHEMATIC ILLUSTRATION OF APPARATUS

holder preferably, at the rate of 1 revolution per 50 revolutions of the drum.

NOTE — With this lateral movement, the test piece passes over any one area of the abrasive cloth four times.

The centre axis of the holder shall have an inclination of 3° to perpendicular in the direction of rotation (*see* Fig. 1), and shall be placed directly above the longitudinal axis of the cylinder to within ±1 mm.

The swivel arm and the test piece holder shall be free from vibration during operation, and so disposed that the test piece is pressed against the drum with a vertical force of 10·0±0·2 N obtained by adding mass to the top of the test piece holder. For special purposes, a force of 5·0±0·1 N may be used.

The abrasive cloth shall be attached to the drum using three evenly spaced strips of double-sided adhesive tape extending along the complete length of the cylinder. Care shall be taken to ensure that the abrasive cloth is firmly held so as to present a uniform abrasive surface over the whole area of the cylinder. One of the strips shall be placed where the ends of the abrasive cloth meet. Ideally, the ends should meet exactly, but any gap left between them shall not exceed 2 mm. The adhesive tape shall be about 50 mm wide and not more than 0·2 mm thick.

Placement of the test piece on to the cloth at the beginning of a test run, and its removal after an abrasion run of 40 m (equivalent to 84 revolutions), shall be automatic. In special cases of very high volume loss of the test piece, an abrasion distance of only 20 m (equivalent to 42 revolutions) may be used. If using an abrasion distance of 20 m, a revolution counter or automatic stopping device should be connected to the drum.

To protect the abrasive cloth from damage by the test piece holder, a device for switching off the apparatus just before the lower edge of the test piece holder touches the cloth is recommended.

4.2 Abrasive Cloth — Abrasive cloth made with aluminium oxide of grit 60 (grain size 60), phenolic resin bonded in accordance with IS : 715 (Part 2)-1976*, at least 400 mm wide, 473 mm long and 1 mm average thickness, shall be used as the abrasive medium.

In a test using a non-rotating test piece of the standard rubber described in **B-1**, this abrasive surface shall cause a mass loss between 180 and 220 mg for an abrasion distance of 40 m.

When each new sheet of cloth is first used, the direction of motion shall be indicated on the sheet, as it is important that the same direction be used for all subsequent test runs.

Notes on a suitable abrasive cloth are given in Appendix A.

4.3 Hollow Drill (*see* Fig. 2) — The drill may be required for the preparation of test pieces (*see* **5.1**). The frequency of rotation of drill needs to be at least 1 000 min^{-1} for most rubbers, and even higher for rubbers with a hardness of less than 50 IRHD [*see* IS : 3400 (Part 2) - 1980*].

4.4 Balance — The balance shall be of sufficient accuracy to enable the mass loss of a test piece to be determined to ± 1 mg.

4.5 Standard Rubbers — Specifications for standard rubbers are given in detail in Appendix B.

5. TEST PIECE

5.1 Type and Preparation — The test pieces shall be cylindrical in shape, of diameter 16±0·2 mm, with a minimum height of 6 mm.

Test pieces are normally prepared using the hollow drill (*see* **4.3**). During cutting, the cutting edge should be lubricated with water to which a wetting agent has been added. Punching of the test pieces is not permitted.

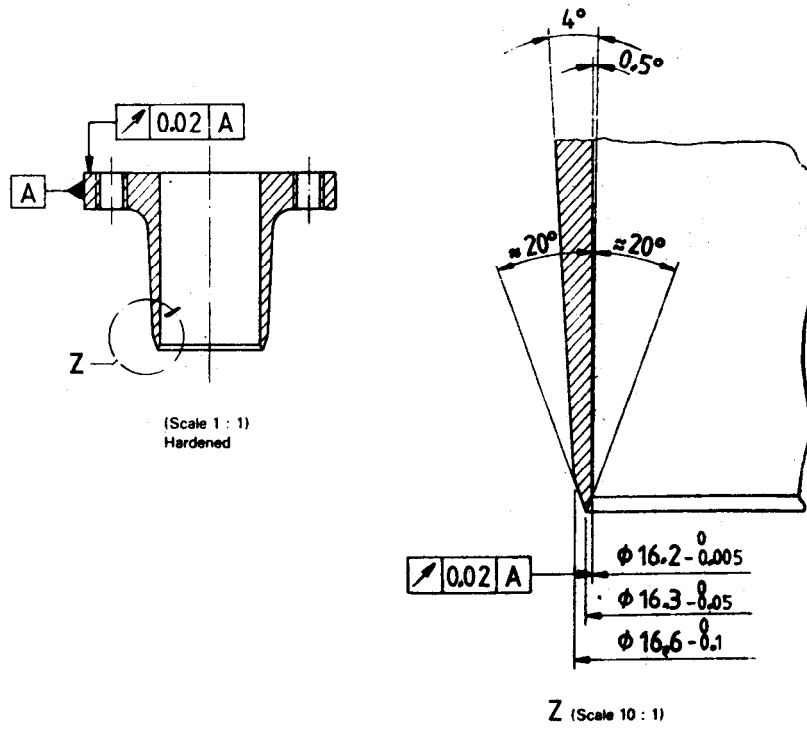
Alternatively, test pieces may be vulcanized in a mould.

If test pieces of required thickness are not available, the necessary thickness may be obtained by bonding a piece of the test rubber to a base element of hardness not less than 80 IRHD. The thickness of the test rubber should not be less than 2 mm.

5.2 Number — Three test runs shall be carried out. This will normally require three test pieces but only one test piece may be necessary if the mass loss per run is very low.

*Specification for coated abrasives: Part 2 Special and mechanized applications (*third revision*).

*Methods of test for vulcanized rubbers: Part 2 Hardness (*first revision*).



All dimensions in millimetres.

FIG. 2 HOLLOW DRILL FOR TEST PIECE PREPARATION

5.3 Time Interval Between Vulcanization and Testing — For all test purposes the minimum time between vulcanization and testing shall be 16 h. For non-product tests, the maximum time between vulcanization and testing shall be 4 weeks and, for evaluations intended to be comparable, the tests, as far as possible, shall be carried out after the same time interval. For product tests, whenever possible, the time between vulcanization and testing shall not exceed 4 months. In other cases, tests shall be made within 2 months of the date of receipt of the product by the customer.

5.4 Conditioning — Condition all test pieces at standard laboratory temperature 27±2°C for a minimum period of 16 h immediately before testing.

NOTE — For some rubbers which are sensitive to moisture, the humidity should also be controlled.

6. TEST TEMPERATURE

6.1 The test shall be carried out at a temperature of 27±2°C.

During a test run, there may be a considerable increase in temperature at the abrading interface which may lead to temperature rises within the test piece. For the purposes of this standard, such temperature rises are to be disregarded, the temperature of test being that of the ambient atmosphere and of the test piece before commencing the test.

When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature.

7. PROCEDURE

7.1 General Test Procedure — Before each test, any rubber debris left on abrasive cloth from a previous abrasion test shall be removed with a brush. A strong brush of about 55 mm diameter and about 70 mm length is recommended for this purpose. In some cases, a blank test with a standard rubber will effectively clean the abrasive cloth.

The test run may be carried out with the test piece either rotating or stationary (non-rotating). For Method A (*see* **8.1**), the non-rotating test piece shall be used. For Method B (*see* **8.2**), the rotating test piece is preferred but the non-rotating test piece may also be used. The test piece used shall be stated in the test report because the results obtained by these two procedures may differ. For measurements intended to be comparable, the same conditions shall be used.

Weigh the test piece to the nearest 1 mg. Fix the test piece in the test piece holder in such a way that a length of $2{\cdot}0 \pm 0{\cdot}1$ mm protrudes from the opening. This length shall be controlled by means of a gauge.

The test piece should be pressed against the drum with a vertical force of $10 \pm 0{\cdot}2$ N. If, for special cases, the vertical force is reduced to $5 \pm 0{\cdot}1$ N, this shall be stated in the test report because the severity of abrasion is lower.

Move the test piece holder and sledge to the starting point, place the test piece on the abrasive cloth and set the cylinder in motion. Check for vibration in the test piece holder. This test method does not yield meaningful results if there is abnormal vibration in the test piece holder. The test run is stopped automatically after an abrasion distance of 40 m. When relatively large mass losses (usually more than 400 mg in 40 m) occur, the test run may be stopped after 20 m, and the length of the exposed test piece reset to $2{\cdot}0 \pm 0{\cdot}2$ mm so that the test may be restarted and completed. At no time shall the height of the test piece be less than 5 mm. If the mass loss is greater than 600 mg in 40 m, the test should only be carried out for half distance (that is 20 m) and this should be stated in the test report. The results should be multiplied by 2 so that the mass loss may still be given for an abrasion distance of 40 m.

Weigh the test piece to the nearest 1 mg after the test run. Sometimes, a small edge hanging from the test piece has to be pulled off before weighing, specially if a non-rotating test piece is used.

Perform three test runs on each rubber under test. Normally, only one run per test piece is carried out but if the mass loss is relatively small, up to three test runs may be carried out on the same test piece. When repeat runs are made on the same test piece, sufficient time shall be allowed between such runs for the temperature of the whole of the test piece to return to standard laboratory temperature. For non-rotating test pieces, care shall be taken to ensure that the test piece is always placed in the sample holder in the same way. If a series of rubbers is being tested, all three test runs on the same rubber shall be carried out consecutively.

7.2 Density — Determine the density of the test material by the method specified in IS : 3400 (Part 9) - 1978*.

7.3 Comparison Against Standard Rubbers — In this standard, the test rubbers are compared against standard rubbers. Two standard rubbers are specified in Appendix B for use with the two methods of expressing results (*see* **8**). That specified in **B-1** is intended for use in Method A where the abrasion resistance is expressed as relative volume loss ΔV (*see* **8.1**). That specified in **B-2** is intended for use in Method B where the abrasion resistance is expressed as an abrasion resistance index, ARI (*see* **8.2**).

The mass loss of a standard rubber shall be determined by carrying out a minimum of three test runs both before and after each test series following the procedure in **7.1**. There shall be a maximum of three test rubbers in each test series.

For rubbers which have a tendency to smear, the mass loss of the standard rubber shall be determined after each test run. In extreme cases of smearing, there will be a considerable reduction in mass loss of the standard rubber measured after the test run compared to that measured before the test run. This is due to the fact that in the test run, the abrasive cloth is being 'cleaned' by the standard rubber, as opposed to the standard rubber being abraded by the cloth. If the reduction in mass loss of the standard rubber is greater than 10 percent, the method is not valid.

*Methods of test for vulcanized rubbers: Part 9 Density (*first revision*).

8. EXPRESSION OF RESULT

8.0 The results may be expressed either as a relative volume loss (Method A — *see* **8.1**) or as an abrasion resistance index (Method B — *see* **8.2**).

Calculate the mean value of mass losses of the test rubber, m, and of the standard rubber, m_s, from the three and six separate determinations, respectively.

Calculate the volume losses of the test rubber, V_t, and of the standard rubber, V_s (for Method B only), from the respective mass losses and densities.

8.1 Method A — Relative Volume Loss, ΔV—In this method, the standard rubber specified in **B-1** is used. The non-rotating test piece shall be used for both the test rubber and the standard rubber. The measured mass loss of the standard rubber using a non-rotating test piece shall be within the range 180 to 220 mg.

The relative volume loss (*see* **2.2**) is given by the formula:

$$\Delta V = V_t \times \frac{200}{m_s}$$

where

V_t = volume loss, in cubic millimetres, of the test rubber; and

m_s = mass loss, in milligrams, of the standard rubber (*see* **B-1**) using a non-rotating test piece.

NOTE — The non-rotating test piece is used because of considerable experience obtained previously with this method using the non-rotating test piece.

8.2 Method B — Abrasion Resistance Index, ARI — In this method, the standard rubber specified in **B-2** is used. The same type of test piece (rotating or non-rotating) shall be used for both the test rubber and the standard rubber.

The abrasion resistance index (*see* **2.3**) is given by the formula:

$$\text{ARI} = \frac{V_s}{V_t} \times 100$$

where

V_s = volume loss, in cubic millimetres, of the standard rubber (*see* **B-2**); and

V_t = volume loss, in cubic millimetres, of the test rubber.

NOTE — The rotating test piece is the preferred test piece because the abrasion loss is more uniform over the whole surface of the test piece in contact with the abrasive cloth.

9. TEST REPORT

9.1 The test report shall include the following particulars:

a) Sample details

1) Full description and origin;
2) Compound details, cure time and temperature, if available; and
3) Method of preparation of test pieces from the sample that is whether cut or moulded.

b) Test method: reference to this Indian standard

c) Test details

1) Standard laboratory temperature used,
2) Whether a non-rotating or rotating test piece was used,
3) Type of standard rubber used, and
4) Any deviations from the test procedure, specially if the test run comprised only half the abrasion distance or if half the vertical force was used.

d) Test result

1) Either the relative volume loss or the abrasion resistance index,
2) Standard deviation of test result, and
3) Density.

e) Date of test.

APPENDIX A

(*Clause* 4.2)

NOTES ON A SUITABLE ABRASIVE CLOTH

A-1. A suitable abrasive cloth is produced commercially. It comprises corundum particles of grain size 60 that is passing through a 60 mesh sieve, bonded to a twill cloth with a phenolic resin. As produced, the abrasive cloth causes an abrasion loss of more than 300 mg when the standard rubber specified in **B-1** is tested using a non-rotating test piece. It is necessary to perform one or two runs with a steel test piece to reduce the abrasive loss to about 210 to 220 mg. Experience has shown that minimum of a few hundred runs may be carried out with this type of cloth.

NOTE — Abrasive cloth produced and standardized in this manner may be obtained from the Bundesanstalt fur Materialprufung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de controle du caoutchouc (LRCC), 12, rue Carves, F-92120 Montrouge, France.

APPENDIX B

(*Clauses* 4.5 *and* 7.3)

STANDARD RUBBERS

B-0. INTRODUCTION

B-0.1 The use of a standard rubber is intended to minimize the variation in abrasion resistance found between laboratories and between machines operating under nominally identical conditions.

The composition and methods of manufacture of the standard rubbers described below are to be taken as a guide; other formulations may be used provided that they fulfil the requirements given in **B-1.5** and **B-2.4**. The standard rubber described in **B-1** shall be used for the calibration of the abrasive cloth (*see* **4.2**) and for calculation of the relative volume loss, ΔV (*see* **8.1**). The standard rubber described in **B-2** shall be used for determination of abrasion resistance index (*see* **8.2**).

B-1. STANDARD RUBBER FOR DETERMINATION OF RELATIVE VOLUME LOSS, ΔV

B-1.1 Formulation of Standard Rubber — The following test compound may be used for determination of relative volume loss:

Material	*Parts by Mass*
Natural rubber ISNR 5	100·0
Dibenzothiazyl disulphide (*see* IS : 8483-1976*)	1·2
N-isoprophyl - *N*-phenyl - *p*-phenylene-diamine	1·0
Zinc oxide (*see* IS : 3399-1973†)	50·0
HAF carbon black (*see* IS : 7497-1985‡)	36·0
Sulphur (*see* IS : 8851-1978§)	2·5
Total	190·7

*Specification for dibenzothiazyl disulphide.

†Specification for zinc oxide for rubber industry (*first revision*).

‡Specification for high abrasion furnace (HAF) carbon black (*first revision*).

§Specification for sulphur for rubber industry.

B-1.2 Mixing Procedure — Masticate the natural rubber to a Mooney viscosity, ML (1 +4) at 100°C, of 80 ± 5, using a two roll laboratory mill having 150 mm outside diameter and 200 to 270 mm working distance between the guides. The speed of the slow roll shall be 24 ± 0·5 rev/min and the gear ratio shall be 1·4 to 1. Then prepare the mix in an internal mixer. Cool the internal mixer to maintain the temperature at 50 ± 5°C.

	Time (min)
Add the rubber	0
Add the accelerator, antioxidant and zinc oxide	5
Add the carbon black sulphur	8
Discharge	30

Sheet out the mix on an open mill to a thickness of about 10 mm and check the batch mass.

NOTE — Other mixing procedures may be used provided the quality of the standard rubber produced meets the requirements of **B-1.5.**

B-1.3 Vulcanization — Bring the mould to the vulcanization temperature and then insert an unvulcanized piece of mix which has been preheated for 20 min at 70°C. An excess of approximately 10 percent is recommended. Vulcanize in a closed press at 150 ± 2°C for 30 ± 1 min, using a moulding pressure of 3·5 MPa.

Sheets measuring approximately 180 × 120 × 8 mm will provide about 65 test pieces.

B-1.4 Storage — Store the standard sheets in cool, dark place and wrap them with material which protects the sheets from attack by ozone (for example, polyethylene).

B-1.5 Quality — Each batch of standard rubber should be compared to a reference sheet.

NOTE — Reference sheet is obtainable from the Bundesanstalt fur Materialprufung (BAM), Unter den Eichen 87, D-1000 Berlin 45, or the Laboratoire de recherches et de controle du caoutchouc (LRCC), 12, rue Carves, F-92120 Montrouge, France, using an abrasive cloth prepared in accordance with Appendix A.

The quality of standard rubber shall be examined by determining the abrasion resistance of a test piece taken from a corner of the sheet measured using a non-rotating test piece as described in this standard, and then comparing this mass loss with the mean mass loss of a reference sheet in immediate consecutive tests. The differences between the mass losses shall not exceed 8 mg.

A standard rubber sheet shall be considered to be a reference sheet if the mass losses measured at six different places (four at the corners and two in the middle) differ by not more than 10 mg and the mean value differs by not more than 5 mg from the mean value of six single values of another reference sheet.

NOTE — It is permitted to carry out three test runs on the same test piece.

B-2. STANDARD RUBBER FOR DETERMINATION OF ABRASION RESISTANCE INDEX, ARI

B-2.1 Formulation of Standard Rubber — The following test compound may be used for determination of abrasion resistance index:

Material	*Parts by Mass*
Natural rubber (ISNR 5)	100·0
Stearic acid (*see* IS : 1675-1971*)	2·0
Zinc oxide (*see* IS : 3399-1973†)	5·0
HAF carbon black (*see* IS : 7497-1985‡)	50·0
N-isoprophyl-*N'*-phenyl-*p*-phenylene-diamine	1·0
Cyclohexyl-benzothiazole sulphanamide (*see* IS:7069-1973§)	0·5
Sulphur (*see* IS : 8851-1978‖)	2·5
Total	161·0

*Specification for stearic acid, technical (*first revision*).

†Specification for zinc oxide for rubber industry (*first revision*).

‡Specification for high abrasion furnace (HAF) carbon black (*first revision*).

§Specification for benzothiazyl-2-cyclohexyl sulphanamide.

‖Specification for sulphur for rubber industry.

B-2.2 Mixing and Vulcanization — Masticate the natural rubber using two roll mill having 150 mm outside diameter and 260 to 270 mm working distance between the guides. The speed of the slow roll shall be 24 ± 0·5 rev/min and the gear ratio shall be 1·4 to 1. However, an internal mixer instead of mixing mill may be used. Sheets shall be vulcanized at 140°C for 60 minutes.

B-2.3 Storage — Store the standard sheets in a cool, dark place and wrap them with material which protects the sheets from attack by ozone (for example, polyethylene).

B-2.4 Quality — The mass losses for two different batches of standard rubber, determined in accordance with 7, shall agree to within ±10 percent.

NOTE — It has been found that the standard rubber gives an abrasion loss of about 150 mg when tested in accordance with 7, using a rotating test piece.

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